

## PHOSPHORUS

Phosphorus is a federal hazardous air pollutant and was identified as a toxic air contaminant in April 1993 under AB 2728.

CAS Registry Number: 7723-14-0

P

Molecular Formula: P

Phosphorus exists in three main allotropic forms: white, black, and red. When melted, the same liquid is obtained from these forms. Phosphorus atoms exist as symmetrical, tetrahedral  $P_4$  molecules as liquid and vapor below 800 °C; molecules dissociate to  $P_2$  above 800 °C.

Black phosphorus is polymorphic, occurring in orthorhombic crystalline form or at higher pressures in the rhombohedral form. The black solid resembles graphite and is obtained by heating white phosphorus under high pressure. It is very stable and insoluble in most solvents.

White phosphorus is a colorless to yellow, transparent, crystalline solid which darkens on exposure to light. The yellow coloring results from impurities. It has a waxy appearance, high electrical resistivity, is insoluble in water and alcohol, but is soluble in carbon disulfide, some organic solvents, and oils, and has phosphorescent properties at room temperature. There are two allotropic forms (alpha and beta). When exposed to air, phosphorus emits white fumes and can spontaneously ignite. Therefore, it should be stored under water. White phosphorus can form compounds with halogens, sulfur, metals, nitric acid, and alkali hydroxides.

Red phosphorus occurs as a violet-red amorphous powder and exhibits polymorphism. It is less reactive than white phosphorus, although it is flammable at 500 °C, has high electrical resistivity, is insoluble in most solvents, and the properties of red phosphorus are intermediate between white and black. Red phosphorus is obtained by heating white phosphorus at 240 °C with a catalyst (Merck, 1989; Sax, 1987).

### Physical Properties of Phosphorus

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Synonyms: black phosphorus = none  
white phosphorus = yellow phosphorus; Bonide Blue Death Rat Killer; Rat-Nip  
red phosphorus = phosphorus, amorphous, red

Molecular Weight:	30.97376
Boiling Point:	280 °C
Melting Point:	44.1 °C (white) 590 °C (black/red)
Vapor Pressure	1 mm Hg at 43 atm (white)
Vapor Density	4.42 (white) (water = 1) 4.77 (red) (water = 1)
Density/Specific Gravity at 20/4 °C:	1.88 (white) (water = 1) 2.70 (black) 2.34 (red)
Conversion Factor:	1 ppm = 1.27 mg/m <sup>3</sup>

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(Merck, 1989; Sax, 1989; U.S. EPA, 1994a)

### SOURCES AND EMISSIONS

#### A. Sources

White phosphorus is used in rodenticides, smoke screens, tracer bullets, fertilizers, and gas analysis. Red phosphorus is used to manufacture phosphoric acid and other phosphorus compounds, phosphor bronzes, and metallic phosphides, and as an additive to semiconductors, electroluminescent coatings, safety matches, and fertilizers (Merck, 1989).

Phosphorous is registered as a vertebrate control agent. It is used for the control of rodents, where they have become a pest problem. The licensing and regulation of pesticides for sale and use in California are the responsibility of the Department of Pesticide Regulation (DPR). Information presented in this fact sheet regarding the permitted pesticidal uses of phosphorous has been collected from pesticide labels registered for use in California and from DPR's pesticide databases. This information reflects pesticide use and permitted uses in California as of October 15, 1996. For further information regarding the pesticidal uses of this compound, please contact the Pesticide Registration Branch of DPR (DPR, 1996).

The primary stationary sources that have reported emissions of phosphorus and phosphorus compounds in California are electrical services, crude petroleum and natural gas extraction, and electrical, gas and sanitary services (ARB, 1997b).

#### B. Emissions

Toxic Air Contaminant Identification  
List Summaries - ARB/SSD/SES

September 1997

The total emissions from stationary sources in California are estimated to be at least 41,000 pounds per year phosphorus and at least 56,000 pounds per year for phosphorus compounds, based on data reported under the Air Toxics “Hot Spots” Program (AB 2588) (ARB, 1997b).

### C. Natural Occurrence

Phosphorus is a constituent of the earth's crust at about 0.12 percent. It doesn't occur free in nature, but is found in the form of phosphates in different minerals such as chlorapatite, fluorapatite, vivianite, wavellite, and phosphorite. Phosphorite nodules on the ocean floor and fertile soil contain phosphorus. Phosphorus is found in small amounts in granite. It is an essential element for protoplasm, bone, and nervous tissue (Merck, 1989; Sax, 1987).

## AMBIENT CONCENTRATIONS

Phosphorus is routinely monitored by the statewide Air Resources Board air toxics network. The network's mean concentration of phosphorus from January 1996 through December 1996 is estimated to be 55.9 nanograms per cubic meter or 0.04 parts per billion (ARB, 1997c).

## INDOOR SOURCES AND CONCENTRATIONS

In a field study conducted in southern California, investigators collected particles (PM<sub>10</sub>) inside 178 homes and analyzed the particle samples for selected elements, including phosphorus. Two consecutive 12-hour samples were collected inside and immediately outside each home. Phosphorus was present in measurable amounts in less than 30 percent of the indoor or outdoor samples (Pellizzari et al., 1992).

## ATMOSPHERIC PERSISTENCE

Phosphorus will exist in the particle phase in the atmosphere, and hence is subject to wet and dry deposition. The average half-life and lifetime for particles in the troposphere is estimated to be about 3.5 to 10 days and 5 to 15 days, respectively (Balkanski et al., 1993; Atkinson, 1995).

## AB 2588 RISK ASSESSMENT INFORMATION

The Office of Environmental Health Hazard Assessment reviews risk assessments submitted under the Air Toxics “Hot Spots” Program (AB 2588). Of the risk assessments reviewed as of December 1996, for non-cancer health effects, phosphorus contributed to the total hazard index in 6 of the approximately 89 risk assessments reporting a total chronic hazard index greater than 1 (OEHHA, 1996b).

## HEALTH EFFECTS

Probable routes of human exposure to phosphorus are inhalation, ingestion, and dermal

contact (Sittig, 1991).

**Non-Cancer:** Phosphorus is extremely toxic to humans and short-term exposure may be fatal. Acute overexposure may adversely affect the liver, kidney, cardiovascular, and gastrointestinal systems (U.S. EPA, 1994a). Yellow phosphorus fumes are highly irritating to the respiratory tract and also cause severe eye irritation. On contact with the skin it may ignite and produce severe skin burns with blistering. Red phosphorus irritates the eyes (Sittig, 1991). Long-term exposure to white phosphorus may result in necrosis of the jaw, known as “phossy jaw” (U.S. EPA, 1994a).

A chronic non-cancer Reference Exposure Level (REL) of  $7.0 \times 10^{-2}$  micrograms per cubic meter is listed for white phosphorus in the California Air Pollution Control Officers Association Air Toxics “Hot Spots” Program, Revised 1992 Risk Assessment Guidelines. The toxicological endpoint considered for chronic toxicity is the reproductive system including teratogenic and developmental effects (CAPCOA, 1993). The United States Environmental Protection Agency (U.S. EPA) has established an oral Reference Dose (RfD) of  $2 \times 10^{-5}$  milligrams per kilogram per day for white phosphorus based on parturition mortality and forelimb hair loss in rats. The U.S. EPA estimates that consumption of this dose or less, over a lifetime, would not likely result in the occurrence of chronic, non-cancer effects. The Reference Concentration (RfC) for white phosphorus is under review by the U.S. EPA (U.S. EPA, 1994a).

No information is available on adverse reproductive or developmental effects in humans. A high maternal mortality rate was reported from oral exposure to white phosphorus in an animal study (U.S. EPA, 1994a).

**Cancer:** No information is available regarding the carcinogenic effects of white phosphorus in humans or animals. The U.S. EPA has classified white phosphorus in Group D: Not classifiable as to human carcinogenicity (U.S. EPA, 1994a). The International Agency for Research on Cancer has not classified phosphorus as to its carcinogenicity (IARC, 1987a).